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This handbook for the port of Livorno, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.

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SEVERE WEATHER GUIDE: MEDITERRANEAN PORTS.

20. LIVORNO.

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CONTENTS

FOREWORD

This handbook on Mediterranean Ports was developed as part of an ongoing effort at the Naval Environmental Prediction Research Facility to create products for direct application to Fleet operations. The research was conducted in response to Commander Naval Oceanography Command (COMNAVOCEANCOM) requirements validated by the Chief of Naval Operations (OP-096).

As mentioned in the preface, the Mediterranean region is unique in that several areas exist where local winds can cause dangerous operating conditions. This handbook will provide the ship's captain with assistance in making decisions regarding the disposition of his ship when heavy winds and seas are encountered or forecast at various port locations.

Readers are urged to submit comments, suggestions for changes, deletions and/or additions to Naval Oceanography Command Center (NAVOCEANCOMCEN), Rota with a copy to the oceanographer, COMSIXTHFLT. They will then be passed on to the Naval Environmental Prediction Research Facility for review and incorporation as appropriate. This document will be a dynamic one, changing and improving as more and better information is obtained.

W. L. SHUTT
Commander, U.S. Navy

PORT INDEX

The following is a tentative prioritized list of Mediterranean Ports to be evaluated during the five-year period 1988-92, with ports grouped by expected year of the port study's publication. This list is subject to change as dictated by circumstances and periodic review.

1988 NO.	PORT
1	GAETA, ITALY
2	NAPLES, ITALY
3	CATANIA, ITALY
4	AUGUSTA BAY, ITALY
5	CAGLIARI, ITALY
6	LA MADDALENA, ITALY
7	MARSEILLE, FRANCE
8	TOULON, FRANCE
9	VILLEFRANCHE, FRANCE
10	MALAGA, SPAIN
11	NICE, FRANCE
12	CANNES, FRANCE
13	MONACO
14	ASHDOD, ISRAEL
15	HAIFA, ISRAEL
16	BARCELONA, SPAIN
17	PALMA, SPAIN
18	IBIZA, SPAIN
19	POLLENSA BAY, SPAIN
20	LIVORNO, ITALY
21	LA SPEZIA, ITALY
22	VENICE, ITALY
23	TRIESTE, ITALY
24	CARTAGENA, SPAIN
25	VALENCIA, SPAIN
	SAN REMO, ITALY
	GENOA, ITALY

1989	PORT
	SPLIT, YUGOSLAVIA
	DUBROVNIK, YUGOSLAVIA
	TARANTO, ITALY
	PALERMO, ITALY
	MESSINA, ITALY
	TAORMINA, ITALY
	PORTO TORRES, ITALY

1990	PORT
	BENIDORM, SPAIN
	ROTA, SPAIN
	TANGIER, MOROCCO
	PORT SAID, EGYPT
	ALEXANDRIA, EGYPT
	ALGIERS, ALGERIA
	TUNIS, TUNISIA
	GULF HAMMAMET, TUNISIA
	GULF OF GABES, TUNISIA
	SOUDA BAY, CRETE

1991	PORT
	PIRAEUS, GREECE
	KALAMATA, GREECE
	THESSALONIKI, GREECE
	CORFU, GREECE
	KITHIRA, GREECE
	VALETTA, MALTA
	LARNACA, CYPRUS

1992	PORT
	ANTALYA, TURKEY
	ISKENDERUN, TURKEY
	IZMIR, TURKEY
	ISTANBUL, TURKEY
	GOLCUK, TURKEY
	GULF OF SOLLUM

PREFACE

Environmental phenomena such as strong winds, high waves, restrictions to visibility and thunderstorms can be hazardous to critical Fleet operations. The cause and effect of several of these phenomena are unique to the Mediterranean region and some prior knowledge of their characteristics would be helpful to ship's captains. The intent of this publication is to provide guidance to the captains for assistance in decision making.

The Mediterranean Sea region is an area where complicated topographical features influence weather patterns. Katabatic winds will flow through restricted mountain gaps or valleys and, as a result of the venturi effect, strengthen to storm intensity in a short period of time. As these winds exit and flow over port regions and coastal areas, anchored ships with large 'sail areas' may be blown aground. Also, hazardous sea state conditions are created, posing a danger for small boats ferrying personnel to and from port. At the same time, adjacent areas may be relatively calm. A glance at current weather charts may not always reveal the causes for these local effects which vary drastically from point to point.

Because of the irregular coast line and numerous islands in the Mediterranean, swell can be refracted around such barriers and come from directions which vary greatly with the wind. Anchored ships may experience winds and seas from one direction and swell from a different direction. These conditions can be extremely hazardous for tendered vessels. Moderate to heavy swell may also propagate outward in advance of a storm resulting in uncomfortable and sometimes dangerous conditions, especially during tending, refueling and boating operations.

This handbook addresses the various weather conditions, their local cause and effect and suggests some evasive action to be taken if necessary. Most of the major ports in the Mediterranean will be covered in the handbook. A priority list, established by the Sixth Fleet, exists for the port studies conducted and this list will be followed as closely as possible in terms of scheduling publications.

RECORD OF CHANGES

CHANGE NUMBER	DATE OF CHANGE	DATE ENTERED	PAGE NUMBER	ENTERED BY

1. GENERAL GUIDANCE

1.1 DESIGN

This handbook is designed to provide ship captains with a ready reference on hazardous weather and wave conditions in selected Mediterranean harbors. Section 2, the captain's summary, is an abbreviated version of section 3, the general information section intended for staff planners and meteorologists. Once section 3 has been read, it is not necessary to read section 2.

1.1.1 Objectives

The basic objective is to provide ship captains with a concise reference of hazards to ship activities that are caused by environmental conditions in various Mediterranean harbors, and to offer suggestions for precautionary and/or evasive actions. A secondary objective is to provide adequate background information on such hazards so that operational forecasters, or other interested parties, can quickly gain the local knowledge that is necessary to ensure high quality forecasts.

1.1.2 Approach

Information on harbor conditions and hazards was accumulated in the following manner:

A. A literature search for reference material was performed.

B. Cruise reports were reviewed.

C. Navy personnel with current or previous area experience were interviewed.

D. A preliminary report was developed which included questions on various local conditions in specific harbors.

E. Port/harbor visits were made by NEPRF personnel; considerable information was obtained through interviews with local pilots, tug masters, etc; and local reference material was obtained.

F. The cumulative information was reviewed, combined, and condensed for harbor studies.

1.1.3 Organization

The Handbook contains two sections for each harbor. The first section summarizes harbor conditions and is intended for use as a quick reference by ship captains, navigators, inport/at sea OOD's, and other interested personnel. This section contains:

A. a brief narrative summary of environmental hazards,

B. a table display of vessel location/situation, potential environmental hazard, effect-precautionary/evasion actions, and advance indicators of potential environmental hazards,

C. local wind wave conditions, and

D. tables depicting the wave conditions resulting from propagation of deep water swell into the harbor.

The swell propagation information includes percent occurrence, average duration, and the period of maximum wave energy within height ranges of greater than 3.3 feet and greater than 6.6 feet. The details on the generation of sea and swell information are provided in Appendix A.

The second section contains additional details and background information on seasonal hazardous conditions. This section is directed to personnel who have a need for additional insights on environmental hazards and related weather events.

1.2. CONTENTS OF SPECIFIC HARBOR STUDIES

This handbook specifically addresses potential wind and wave related hazards to ships operating in various Mediterranean ports utilized by the U.S. Navy. It does not contain general purpose climatology and/or comprehensive forecast rules for weather conditions of a more benign nature.

The contents are intended for use in both pre-visit planning and in situ problem solving by either mariners or environmentalists. Potential hazards related to both weather and waves are addressed. The oceanographic information includes some rather unique information relating to deep water swell propagating into harbor shallow water areas.

Emphasis is placed on the hazards related to wind, wind waves, and the propagation of deep water swell into the harbor areas. Various vessel locations/situations are considered, including moored, nesting, anchored, arriving/departing, and small boat operations. The potential problems and suggested pre-cautionary/evasive actions for various combinations of environmental threats and vessel location/situation are provided. Local indicators of environmental hazards and possible evasion techniques are summarized for various scenarios.

CAUTIONARY NOTE: In September 1985 Hurricane Gloria raked the Norfolk, VA area while several US Navy ships were anchored on the muddy bottom of Chesapeake Bay. One important fact was revealed during this incident: Most all ships frigate size and larger dragged anchor, some more than others, in winds of over 50 knots. As winds and waves increased, ships 'fell into' the wave troughs, BROADSIDE TO THE WIND and become difficult or impossible to control.

This was a rare instance in which several ships of recent design were exposed to the same storm and much effort was put into the documentation of lessons learned. Chief among these was the suggestion to evade at sea rather than remain anchored at port whenever winds of such intensity were forecast.

2. CAPTAIN'S SUMMARY

The Port of Livorno is located on the west coast of the Italian peninsula at approximately 43°33'N 10°19'E. It is on the eastern shore of the Ligurian Sea, about 50 n mi northeast of Corsica (Figure 2-1).

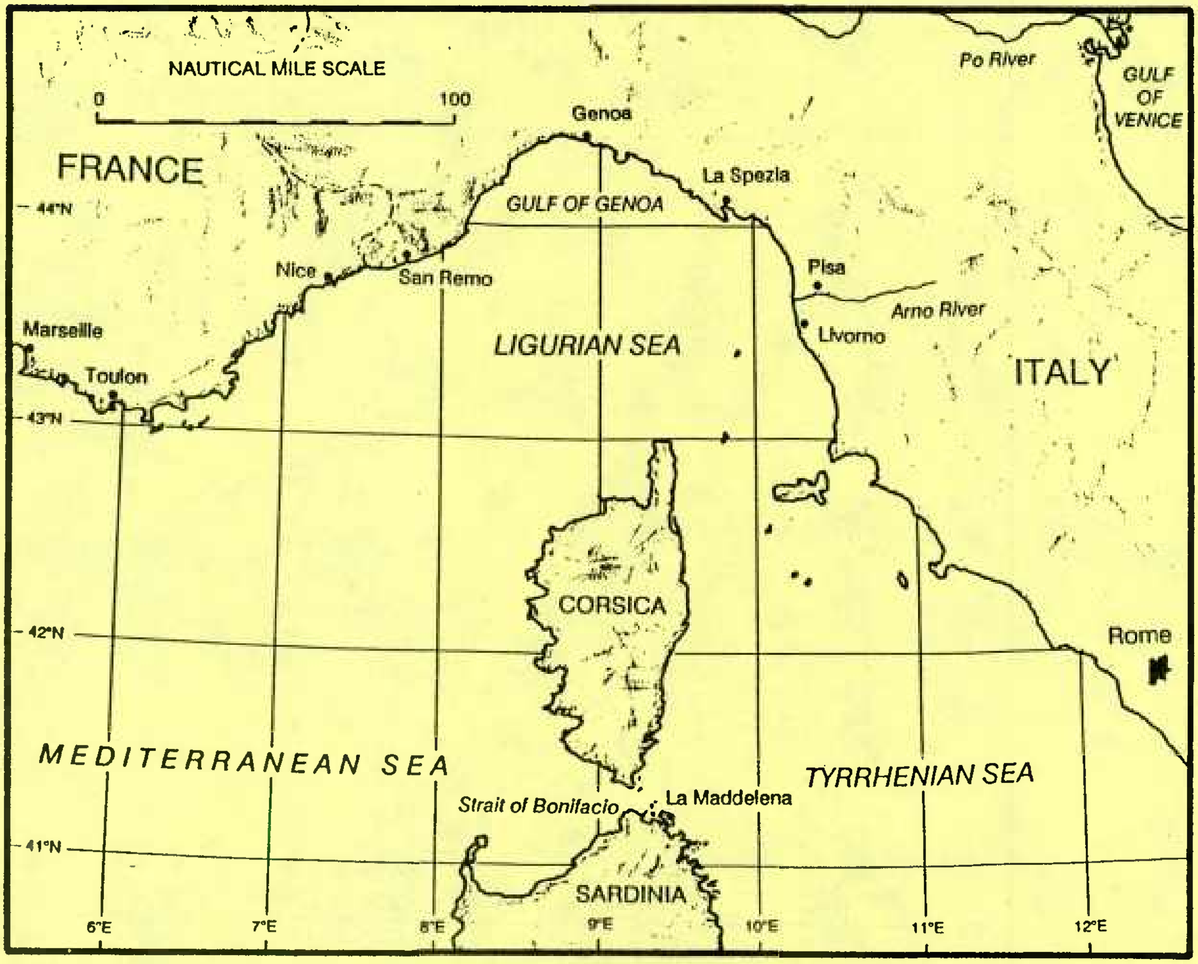


Figure 2-1. Ligurian Sea.

The Port is situated about 6 3/4 n mi south of the mouth of the Arno River on a wide plain which is backed by hills (Hydrographer of the Navy, 1965) (Figure 2-2).

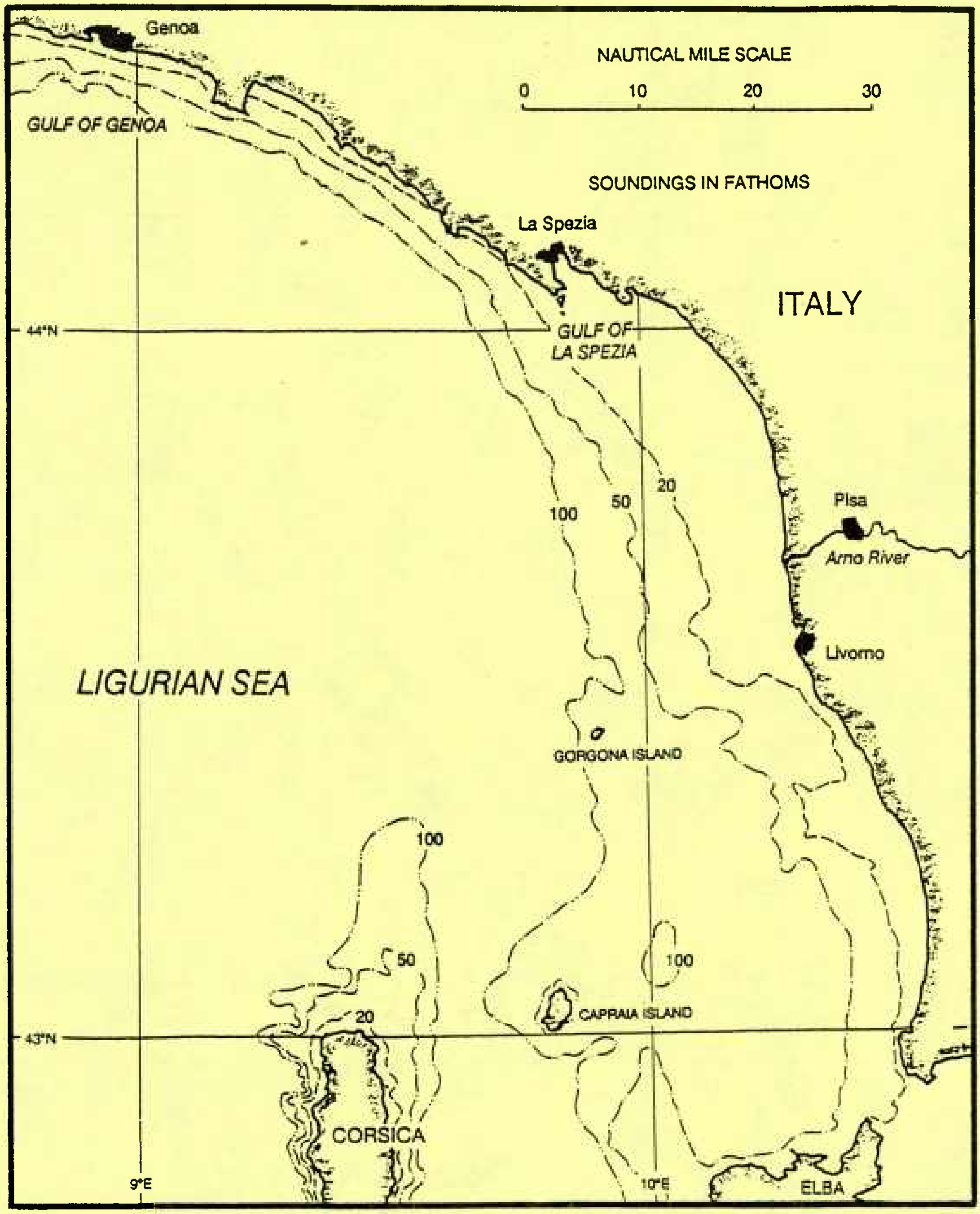


Figure 2-2. Region of the Ports of Livorno and La Spezia.

The western, seaward side of the harbor is protected by a series of breakwaters: Diga Marzocco, which forms the western limit of the northern portion of the harbor; Diga Meloria and Diga Curvilinea, which are joined and form the major western limit of the harbor; and Diga della Vegliaia, a short breakwater which affords limited protection to the southern entrance to the harbor (Figure 2-3). The harbor at the Port of Livorno is divided into 4 primary sections: Avamporto, which is entered through the southern entrance and lies between Diga Curvilinea and Molo Mediceo; Bacino San Stefano, which is formed on the west by Diga Meloria, on the north by Diga Marzocco, and on the southeast by Diga Rettilinea; Porto Nuovo, which lies northeast of Bacino San Stefano; and Porto Vecchio, which consists of Porto Mediceo and Bacino Cappellini (Hydrographer of the Navy, 1965). Two main entrances exist at the Port. The 361 yd (330 m) wide northern entrance lies between the southern end of Diga Marzocco and the eastern side of Diga Meloria. A narrower southern entrance lies just east of the south end of Diga Curvilinea.

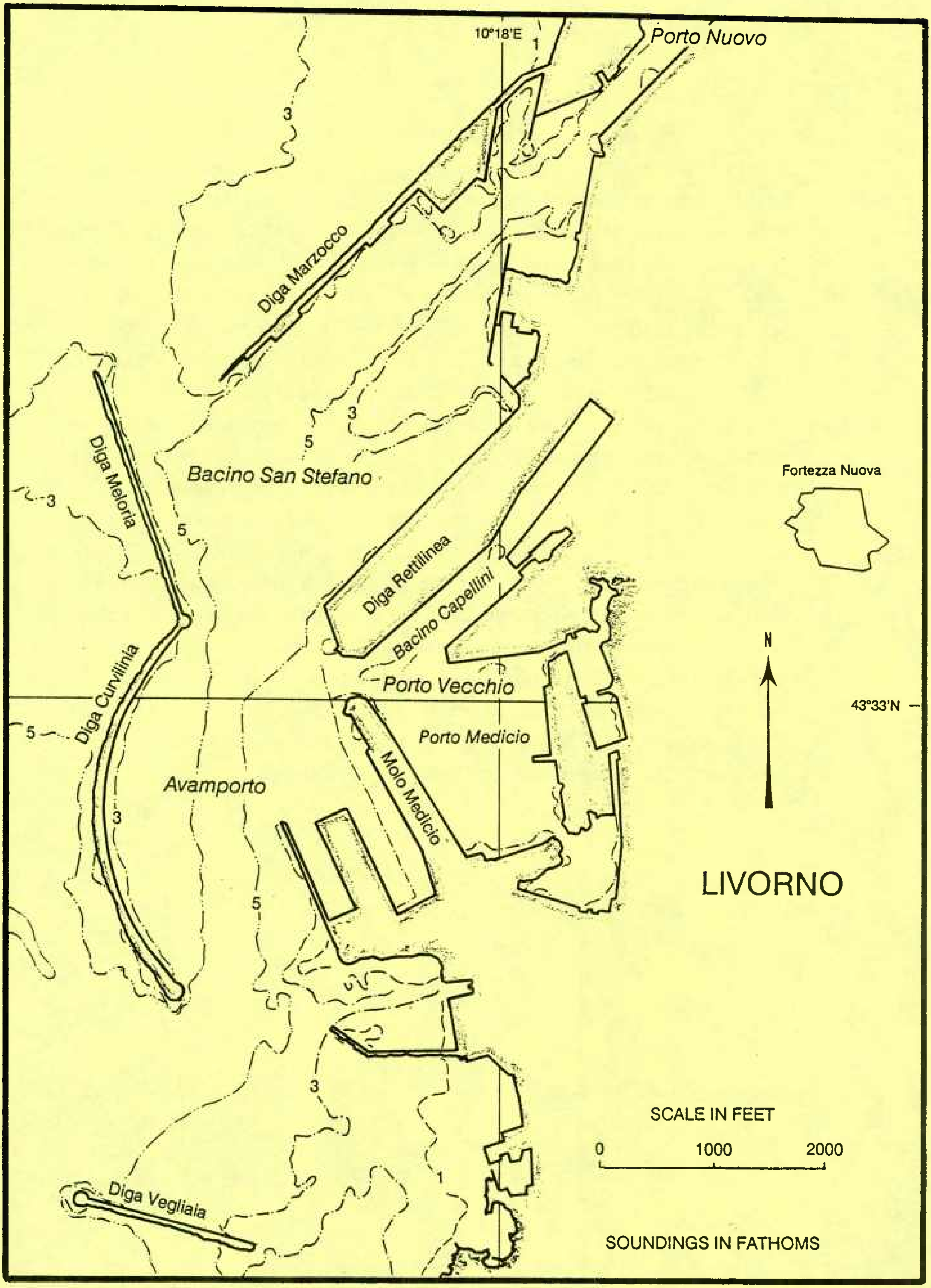


Figure 2-3. Port of Livorno.

U.S. Navy ships usually moor at Porto Mediceo, where "Med-mooring" is used for ships 525 ft (160 m) or smaller with drafts of 28 ft or less. The fleet landing is also in Porto Mediceo. Secondary berths are available at Darsena No. 1 for ships with drafts to 27 ft. The container terminal in Darsena Toscana can also be used if space is available. Ship size and draft is unlimited.

Anchorage is available anywhere between 1 and 1.5 n mi from the breakwater. One anchorage, located 3,600 yd (3,292 m) from the south breakwater and 3,000 yd (2,743 m) from the nearest land, has a bottom of mud, stone, and kelp in 13 to 20 fm (24 to 36 m) of water (FICEURLANT, 1987). A second location, about 1 n mi south of the breakwater and 3/4 to 1 n mi from the coast, has good holding on a mostly mud bottom in water depths of 16 to 93 fm (30 to 170 m). The anchorage at Livorno is considered dangerous because high winds can produce hazardous small boat conditions and cause larger vessels to drag anchor (Brody and Nestor, 1988).

Currents within the harbor confines are usually negligible except as noted below. Outside the breakwaters, the current is generally wind driven, with persistent northwesterly winds during summer producing a strong south-moving current between Secche delia Meloria and the coast. Secche della meloria is a shallow shoal area located about 1 n mi seaward form the north end of Diga Meloria. The shoal area is about 1/2 n mi wide (east-west) and 1 n mi long. The current also affects Avamporto as the current flows in through the north entrance to the harbor and out the south entrance (Hydrographer of the Navy, 1965). Winds from southeast through southwest produce a north-moving current between Secche della Meloria and the coast. Maximum tidal range is about 1.5 ft (0.5 m). A southerly wind can raise the water level in the harbor by as much as 3 ft (0.9 m) (FICEURLANT, 1987).

Specific hazardous conditions, vessel situations, and suggested precautionary/evasive action scenarios are summarized in Table 2-1.

Table 2-1. Summary of hazardous environmental conditions for the Port of Livorno, Italy.

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
1. SW'ly winds/waves * Wind known locally as Lebeccio. * Winter velocities average force 6 to 7 (22-33 kt) but may reach force 8 to 9 (34-47 kt) for periods up to 12 hrs. * Deep water waves commonly reach heights of 10-13 ft (3-4 m). * Swell waves to 10 ft (3 m) may persist after wind abates. * Wave height will be lower in lee of Secche della Meloria.	Advance warning - Lebeccio winds have 2 primary causes: (1) low pressure systems in the Gulf of Genoa, and (2) E'ly spreading of Mistral winds from the Gulf of Lion. The following is an abbreviated listing of various indicators. * Genoa cyclogenesis * Significant cyclogenesis can be expected whenever a cold front crosses France and reaches an existent trough over the Gulf of Genoa. * Genoa lows occur almost simultaneously with the onset of a Mistral in the Gulf of Lion, and invariably form when conditions are right for a Mistral to occur. * Mistral winds * Winds result from a basic circulation that creates a W to E pressure gradient along the S coast of France. The pressure gradient is normally associated with Genoa cyclogenesis. * A wind increase over the open water resulting from the reduction in the braking effect of surface friction as compared to that over land. * A Mistral will start in the Gulf of Lion when 1 of 3 pressure differences is achieved: Perpignan-Marignane (Marseille), 3 mb; Marignane-Nice, 3 mb; or Perpignan-Nice, 6 mb. A difference usually occurs 0-24 hr after a closed Genoa low occurs, but it may occur earlier. * Strongest winds do not occur until after the passage of the upper-level (500 mb) trough, usually well after passage of the surface cold front. * When a 10 mb pressure difference exists between Toulon and Nice, the Mistral will spread E. With only a 2 mb difference, the Mistral will stop near Toulon. * The E limit of the Mistral is normally a line downwind from the W edge of the Alps through San Remo, Italy. * Local indicators * SE winds often precede Lebeccio conditions. The direction then veers to SW, after which it usually takes 4-6 hr for the Lebeccio to attain full force. * Orographic clouds forming on the W side of Monte Nero, a 1,000 ft peak E of Livorno, indicate the start of SW winds. Duration * Lebeccio winds may last for 2 to 3 days. * SW'ly swell waves to 10 ft (3 m) may persist for 12-24 hr after wind abates. Associated weather * If, following the Lebeccio, the winds become SE, the weather will deteriorate and the Lebeccio will return. * If the wind direction veers to N following the Lebeccio, the weather will improve, becoming cool and clear.	(1) Moored - inner harbor. (2) Anchored - outside breakwater. (3) Arriving/departing. (4) Small boats.	(a) Vessels, especially those with large sail areas, may be forced on/off their berths by the wind force. * Doubling of mooring lines may be required to prevent undue movement and/or shifting. * Inner harbor is protected from hazardous waves. (a) THE LIVORNO ANCHORAGE IS CONSIDERED DANGEROUS BECAUSE HIGH WINDS CAN PRODUCE HAZARDOUS SAILING CONDITIONS AND CAUSE LARGE VESSELS TO DRAG ANCHOR. * The Port Captain will order vessels which are not berthed in the harbor to sortie and protect at sea when the winds are forecast to exceed 45 kt. * No viable alternate anchorages exist close by. * Waves in the anchorage E of Secche della Meloria will likely be lower than those in other anchorage areas. (a) Inbound vessels should be aware of wind effects on inner harbor and anchorage. * Those bound for inner harbor should be prepared with additional mooring lines. * Strong SE'ly winds can create a swell which is felt at Livorno, which at times makes it impossible for large vessels to enter the harbor. * Those bound for anchorages should seek an alternate port if strong winds are forecast. * If winds are less than 45 kt, and the anchorage at Livorno must be used, the anchorage E of Secche della Meloria should have lower wave heights than other anchorages. (b) Outbound vessels should prepare for waves to 13 ft (4 m). (a) Small boat operations normally continue until wind exceeds force 4 (11-16 kt). * Inner harbor operations should be largely unaffected. * Boating to/from the anchorages may become hazardous. * Boats making runs to/from the anchorages may find it less hazardous to utilize the N port entrance due to the protective effects of Secche della Meloria.

SEASONAL SUMMARY OF LIVORNO HAZARDOUS WEATHER CONDITIONS

WINTER (November through February):

* SW'ly winds and waves: called Lebeccio, caused by Gulf of Genoa low; average force 6-7 (22-33 kt) may reach force 8-9 (34-47 kt) for up to 12 hours. Deep water waves 10-13 (3-4 m), swell to 10 ft (3 m) lasting 12-24 hours after winds abate.

SPRING (March through May):

* SW'ly winds and waves: speeds to 65 kt have been recorded at Gorgona Island. Spring occurrence of Lebeccio most intense and frequent in March and April.

SUMMER (June through September):

* Thunderstorms: may occur in late summer.

AUTUMN (October):

* Rapid transition form summer to winter type weather.
* SW'ly wind events return by end of October.

NOTE: For more detailed information on hazardous weather conditions see previous Summary Table in this section and the Hazardous Weather Summary in Section 3.

REFERENCES

Brody, L.R. and M.J.R. Nestor, 1980: Regional Forecasting Aids for the Mediterranean Basin, NAVENVPREDRSCHFAC Technical Report TR 80-10. Naval Environmental Prediction Research Facility, Monterey, California 93943-5006.

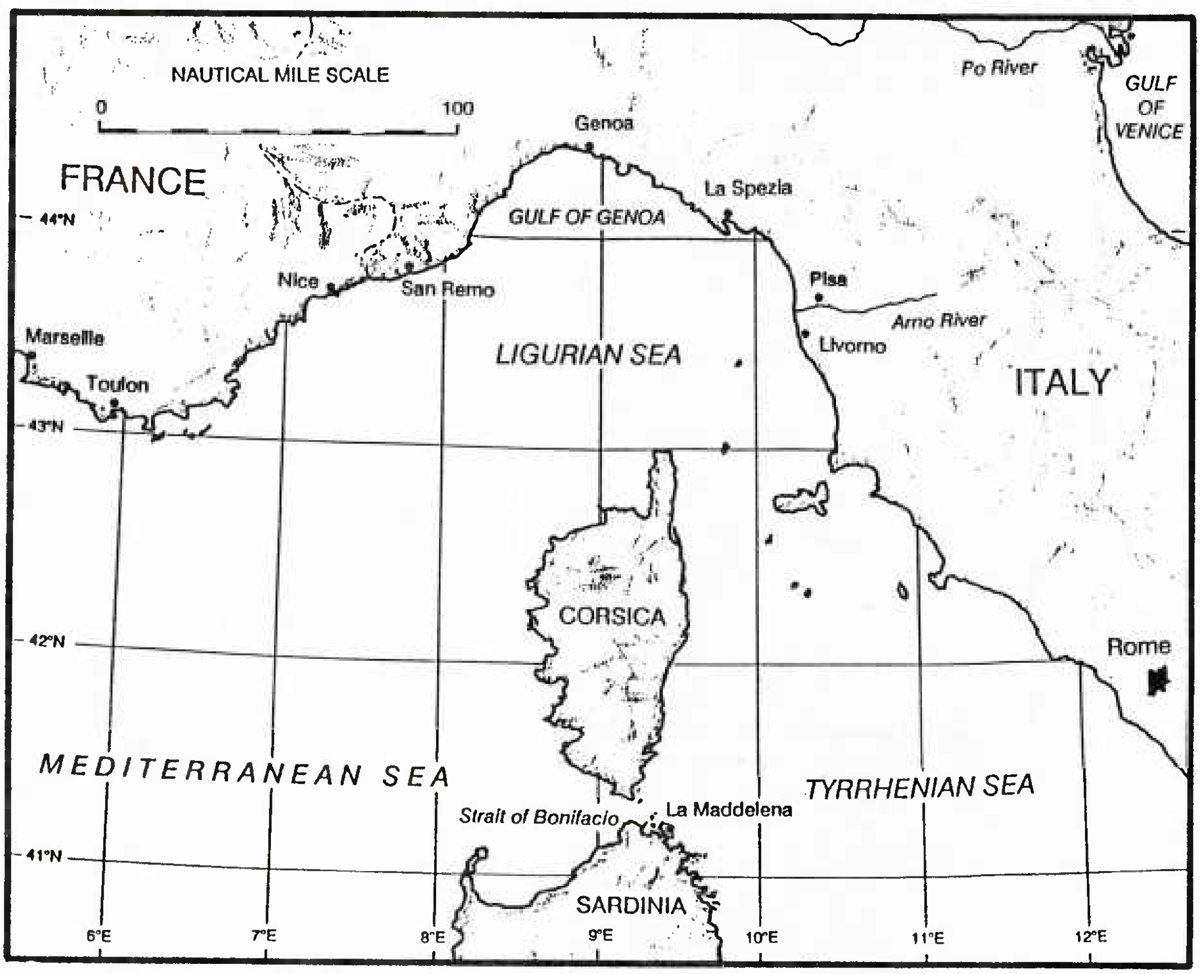
FICEURLANT, 1987: Port Directory for Livorno, (1986), Italy

3. GENERAL INFORMATION

This section is intended for Fleet meteorologists/oceanographers and staff planners. Paragraph 3.5 provides a general discussion of hazards and Table 3-5 provides a summary of vessel locations/situations, potential hazards, effect-precautionary/evasive actions, and advance indicators as well as other information about potential hazards by season.

3.1 Geographic Location

The Port of Livorno is located on the west coast of the Italian Peninsula at approximately 43°33'N 10° 19'E (Figure 3-1). It is on the eastern shore of the Ligurian Sea, about 50 n mi northeast of Corsica.



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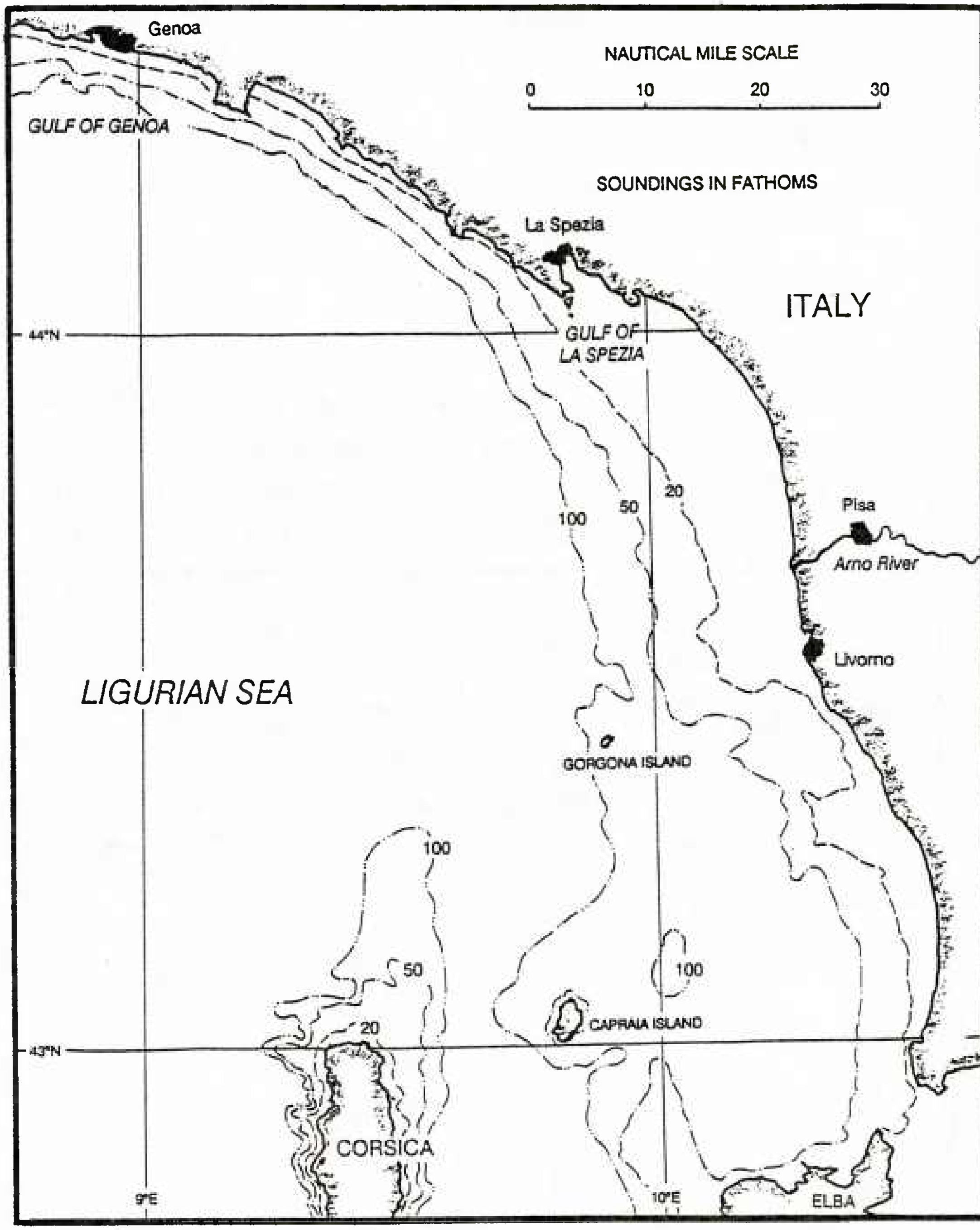
The port is situated about 6 3/4 n mi south of the mouth of the Arno River on a wide plain which is backed by hills (Hydrographer of the Navy, 1965) (Figure 3-2).



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The western, seaward side of the harbor is protected by a series of breakwaters: Diga Marzocco, which forms the western limit of the northern portion of the harbor; Diga Meloria and Diga Curvilinea, which are joined and form the major western limit of the harbor; and Diga della Vegliaia, which is relatively short and affords limited protection to the southern entrance to the harbor (Figure 3-3). The harbor at the Port of Livorno is divided into 4 primary sections: Avamporto, which is entered through the southern entrance and lies between Diga Curvilinea and Molo Mediceo; Bacino San Stefano, which is formed on the west by Diga Meloria, on the north by Diga Marzocco, and on the southeast by Diga Rettilinea; Porto Nuovo, which lies northeast of Bacino San Stefano; and Porto Vecchio, which consists of Porto Mediceo and Bacino Cappellini (Hydrographer of the Navy, 1965). Two main entrances exist at the Port. The north entrance is 361 yd (330 m) wide between the southern end of Diga Marzocco and the eastern side of Diga Meloria. The narrower south entrance lies between the south end of Diga Curvilinea and shallow water produced by a shoal bank which extends west from the east side of the Port.

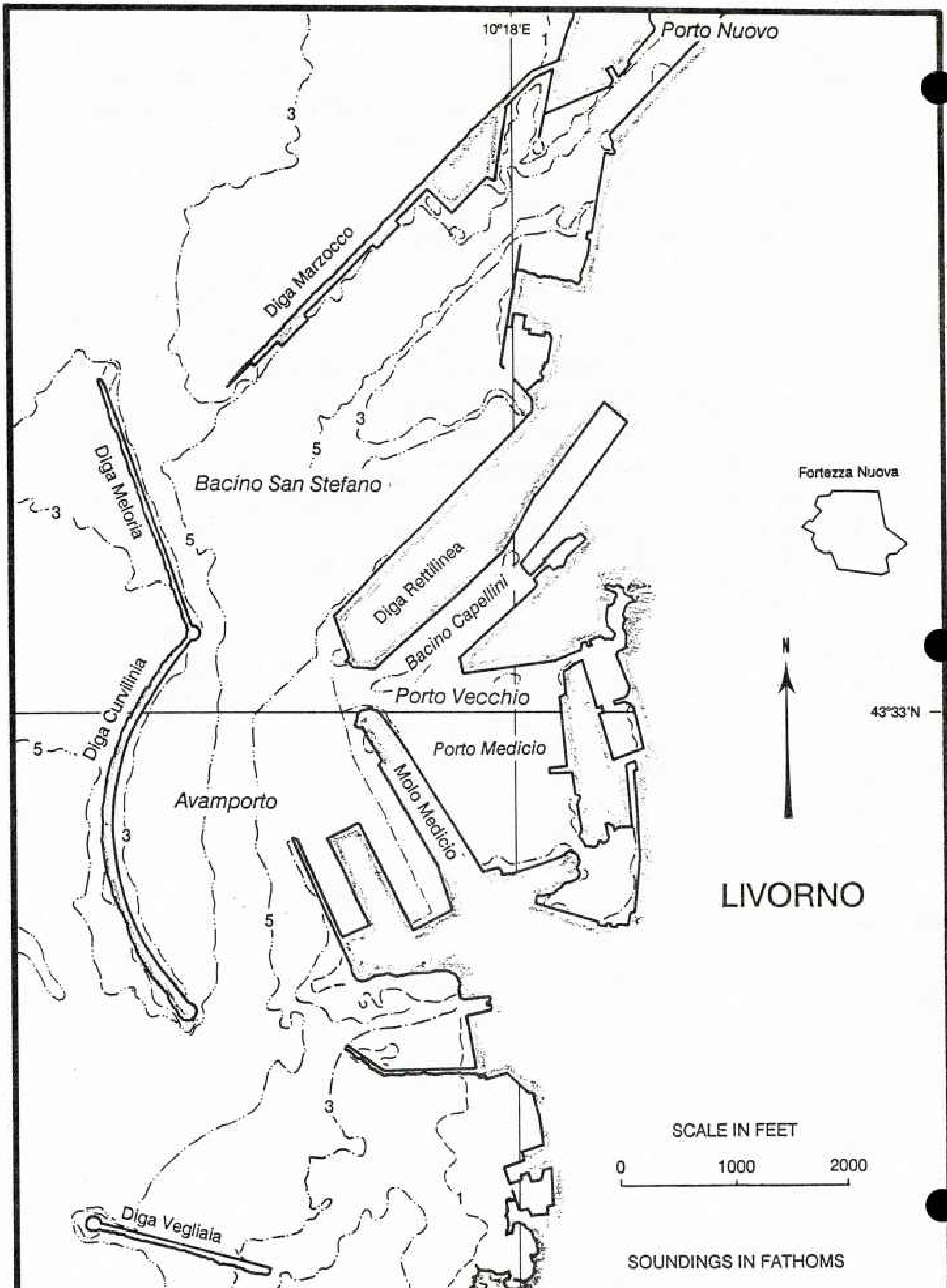

Figure 3-3. Port of Livorno.

U.S. Navy ships mooring at Livorno usually utilize Porto Mediceo, where "Med-mooring" is used for ships 525 ft (160 m) or smaller with drafts of 28 ft or less. The fleet landing is also in Porto Mediceo. Secondary berths are available at Darsena No. 1, for ships with drafts to 27 ft. The container terminal in Darsena Toscana, where ship size and draft is unlimited, can also be used if available.

Anchorage is available anywhere between 1 and 1.5 n mi from the breakwater. One anchorage, situated 3,600 yd (3,292 m) from the south breakwater and 3,000 yd (2,743 m) from the nearest land, has a bottom composed of mud, stone, and kelp in 13 to 20 fm (24 to 36 m) of water (FICEURLANT, 1987). Interviews with local authorities indicate that a large anchorage area is approximately 1 n mi south of the breakwater, 3/4 to 1 n mi from the coast. Water depth varies from 16 to 93 fm (30 to 170 m) with good holding on a bottom composed of mostly mud. The anchorage at Livorno is considered dangerous because high winds can produce hazardous small boat conditions and cause larger vessels to drag anchor (Brody and Nestor, 1980).

3.2 Qualitative Evaluation of the Harbor as a Haven

The portion of the Port of Livorno located inside the protective breakwater system is well protected from waves. Strong outbreaks of wind, primarily from the southwest, locally called Lebeccio, bother ships with large sail areas to the extent that it is advisable to double mooring lines.

According to Mediterranean Pilot, Volume 1, published by the Hydrographer of the Navy, London, England in 1965, strong southeasterly winds, which last about 3 days in winter, generate a swell that reaches Livorno which may make it impossible for large vessels to enter the harbor.

Vessels at anchor outside the breakwaters are exposed to the strong southwesterly Lebeccio winds and the accompanying waves. When winds are forecast to exceed 45 kt, the Port Captain will order vessels which are not berthed to sortie and protect at sea. As indicated above, Brody and Nestor (1980) states: "The anchorage at Livorno is considered dangerous because high winds can produce hazardous sailing conditions and cause larger vessels to drag anchors."

Small boats will normally continue to operate until winds exceed force 4 (11-16 kt). Because of the protective effects of the shallow water over Secche della Meloria, boats making runs to/from the harbor and the anchorages may find it less hazardous to use the northern harbor entrance.

3.3 Currents and Tides

Currents within the confines of the harbor are usually negligible except as noted below. Outside the breakwaters, the current is generally wind driven, with persistent northwesterly winds during summer resulting in a strong south-moving current between Secche della Meloria and the coast. Secche della Meloria is a shallow shoal area located about 1 n mi seaward from the north end of Diga Meloria. The shoal area is about 1/2 n mi wide (east-west) and 1 n mi long. The current also affects Avamporto as the current flows in through the north entrance to the harbor, and out the south entrance (Hydrographer of the Navy, 1965). Winds from southeast through southwest produce a north-moving current between Secche della Meloria and the coast.

Maximum tidal range is about 1.5 ft (0.5 m). A southerly (southeast to southwest) wind can raise the water level in the harbor by up to 3 ft (0.9 m) (U.S. Navy, 1985).

3.4 Visibility

Visibility at Livorno is generally good, but it is occasionally reduced. Early morning land breezes tend to blow smoke and industrial haze from the city towards Secche della Meloria, with the result that landmarks are difficult to distinguish (Hydrographer of the Navy, 1965). During late winter and spring, fog will reduce visibility to near zero on about 6 to 7 days per year. The reduction normally lasts less than 4 hours.

3.5 Hazardous Conditions

Livorno is located close to the Gulf of Genoa, one of the most active areas of cyclogenesis in the world. Consequently, it is subject to frequent periods of unstable, inclement weather, mainly during the autumn, winter, and spring seasons.

A seasonal summary of various known environmental hazards that may be encountered in the Port of Livorno follows.

A. <u>Winter (November through February)</u>

The most persistent and strongest wind at Livorno is from the southwest. Locally called Lebeccio, the wind has two major causes: (1) the circulation associated with a Genoa low, and (2) Mistral winds which spread eastward from the Gulf of Lion. The winds which are caused by Genoa low formation are the most common. In winter, the Lebeccio averages force 6 to 7 (22-33 kt), but may reach force 8 to 9 (34-47 kt) for periods lasting up to 12 hours. Associated waves at the anchorages during Lebeccio conditions will be 10 to 13 ft (3 to 4 m). Swell waves to 10 ft (3 m) may last for 12 to 24 hours after Lebeccio winds abate at Livorno.

The northerly Tramontana winds which are common at other ports along the coast occur only infrequently at Livorno and have little effect on the harbor area due to fetch limitation.

Precipitation is common during this season, with November's 4.4 inches being the greatest average monthly accumulation of the year. While not commonly seen, occasional snowfalls are recorded at Livorno, with January and February having the highest probability of occurrence. The show usually melts quickly as temperatures return to their normal range within a day.

The months of January and February are the coldest of the year, with a daily minimum of about 41°F (5°C) being normal for the period. The median high for the same period is near 52°F (11°C). Because of the relatively low temperatures that are common at Livorno, wind chill (the effect of temperature combined with wind) should be considered when personnel are required to work outside in exposed locations. Table 3-1 can be used to determine the wind chill factor for various temperature and wind combinations.

Table 3-1. Wind Chill. The Cooling power of the wind expressed as "Equivalent Chill Temperature" (adapted from Kotsch, 1983).

Wind Speed		Cooling Power of Wind expressed as "Equivalent Chill Temperature"								
Knots	MPH	Temperature (°F)								
Calm	Calm	40	35	30	25	20	15	10	5	0
		Equivalent Chill Temperature								
3-6	5	35	30	25	20	15	10	5	0	-5
7-10	10	30	20	15	10	5	0	-10	-15	-20
11-15	15	25	15	10	0	-5	-10	-20	-25	-30
16-19	20	20	10	5	0	-10	-15	-25	-30	-35
20-23	25	15	10	0	-5	-15	-20	-30	-35	-45
24-28	30	10	5	0	-10	-20	-25	-30	-40	-50
29-32	35	10	5	-5	-10	-20	-30	-35	-40	-50
33-36	40	10	0	-5	-15	-20	-30	-35	-45	-55

B. Spring (March through May)

The spring season in the central Mediterranean Sea is characterized by periods of stormy winter-type weather associated with a continued high frequency of Genoa lows, which alternate with a number of false starts of relatively settled-summer type weather (Brody and Nestor, 1980). Although Genoa lows can develop during any month, the strongest spring systems occur in March and April. By May, the transition to the more-or-less settled weather of summer proceeds more smoothly. Strong winds are possible throughout the season, with velocities of 65 kt being recorded at Gorgona Island (about 18 n mi west-southwest of Livorno) during March and April, and 58 kt during May.

Southwesterly Lebeccio winds are possible throughout the season as low pressure systems move into or develop in the Gulf of Genoa. Strongest winds are to be expected in March and April. Since late winter and early spring is the period of maximum Mistral frequency and strength in the Gulf of Lion, Lebeccio winds at Livorno which result from an eastward spreading of Mistral winds would also be more frequent and stronger during the same period. In either case, strong Lebeccio winds would be rare and of short duration by the end of May.

Springtime precipitation is at a maximum during March, when an average of 3.2 inches falls. Monthly totals decrease through April to May, when about 2.5 inches can be expected during an average month. Snow has been recorded during March, but is a very rare occurrence. Thunderstorms are possible, and are most probable with the development and movement of a strong Genoa low and its associated frontal system through the Livorno area.

An increase in temperature occurs throughout the season. By May the mean daily maximum and minimum temperatures are 70°F (21°C) and 57°F (14°C) respectively. Wind chill should be considered for personnel working outdoors in exposed locations through mid-April. See Table 3-1.

C. <u>Summer (June through September)</u>

The Summer season brings warm relatively settled weather to Livorno. Lebeccio events are rare and of short duration. A sea/land breeze regime is evident, with most early morning winds being from northeast and east, and afternoon winds from west and northwest.

speeds are light, however, and have negligible effect on harbor operations.

Precipitation reaches its minimum during mid-summer with an average accumulation during July, the driest month, of about 0.8 inch. August is nearly as dry, but the monthly total increases to almost 3.5 inches in September. Thunderstorms may occur during late summer, but are usually widely scattered.

July and August have the highest average temperatures of the year, with 82°F (28°C) and 68°F (20°C) being the mean daily maximum and minimum temperatures during those months.

D. Autumn (October)

According to Brody and Nestor (1980), the autumn season lasts only for the single month of October, and is characterized by an abrupt change to winter-type weather.

The transition to winter-type weather brings an increase in frequency and intensity of Genoa cyclogenesis, and attendant Lebeccio winds at Livorno.

Precipitation amounts continue to increase from the relatively low totals of summer with 3.9 inches being recorded during an average October.

Temperatures decrease from those of late summer, but are still moderate, with 68°F (20°C) and 55°F (13°C) being the mean daily maximum and minimum figures for the month.

3.6 Harbor Protection

As detailed below, that portion of the Port of Livorno inside the breakwaters is well protected from wave action, but is exposed to the effects of wind. The anchorages are located outside the breakwaters and are vulnerable to both.

3.6.1 Wind and weather

Ships moored in the harbor, especially those with large sail areas, are affected by strong winds as they are forced on/off their berths. A doubling of lines is generally sufficient to protect the vessel from undue motion and shifting. Small boats in the harbor continue normal operations until the wind exceeds force 4 (11-16 kt).

Vessels anchored outside the harbor are exposed to strong winds. The Livorno anchorage is considered dangerous because of anchor dragging induced by strong winds on large vessels (Brody and Nestor, 1980). Once the wind reaches 45 kt, the Port Captain will order vessels which are not berthed to sortie to the open sea. Small boat operation to/from the inner harbor and the roadstead will likely be interrupted if winds exceed force 4 (11-16 kt). Small boats may find reduced wave heights be using the northernmost harbor entrance when making runs to/from the roadstead when southwesterly winds are blowing.

3.6.2 Waves

The inner harbor is well protected from waves, so ships moored therein should experience no problems related to wave action.

Vessels in the roadstead are exposed to the brunt of 10 to 13 ft (3 to 4 m) waves which may accompany a strong Lebeccio outbreak. Such an event may make remaining at anchor inadvisable. According to local authorities, swell east of Secche Della Meloria are is lower due to energy lost when crossing the shallow water. Consequently it may be less hazardous to use the northern harbor entrance (between Diga Meloria and Diga Marzocco) for boating operations when a southwesterly swell exists.

Also, according to Hydrographer of the Navy (1965), during and after periods of strong south-easterly winds, a considerable swell is felt in the harbor which at times makes it impossible for large vessels to enter.

3.7 Protective/Mitigating Measures

3.7.1 Sortie/remain in Port

Vessels moored in the inner harbor should be able to remain. Lines should be doubled if strong winds are forecast, especially for vessels with large sail areas.

3.7.2 Moving to a New Anchorage

Anchored vessels should be able to remain in the anchorage unless the wind is forecast to exceed 45 kt. If so, the Port Captain will order vessels not berthed to sortie to the open sea. The anchorage north of the outer breakwater at La Spezia would afford better protection from southwesterly waves than would the other anchorages.

3.8 Local Indicators of Hazardous Weather Conditions

The inner harbor at the Port of Livorno is well sheltered from waves, but is vulnerable to the direct effect of strong wind. The roadstead is located outside the protective breakwater system, and is exposed to the effects of specific winds and waves. Consequently, it is prudent to be aware of forthcoming hazardous weather events. The following guidelines have been compiled from various sources, including on-site interviews with local authorities at Livorno. They are intended to provide additional insight to Fleet meteorologists and enable them to recognize events that indicate changes in weather conditions. Unless otherwise indicated, the guidelines have been adapted from Regional Forecasting Aids for the Mediterranean Basin, NAVENVPREDRSCHFAC Technical Report TR 10-80, authored by L.R. Brody and LCDR M.J.R. Nestor, RN and published by Naval Environmental Prediction Research Facility, Monterey, California 93941 in December 1980.

3.8.1 Southwesterly Lebeccio winds

A. Genoa lows, the most frequent cause of strong southwesterly winds (Lebeccio) at Livorno.

(1) Cyclogenesis

(a) A lee trough often is present in the Gulf of Genoa when a cold or occluded front is moving into western France. This lee trough remains stationary until the arrival of the front, at which time significant cyclogenesis occurs.

(b) A good indication of rapid development of a Genoa low is the appearance of cold air from the northeast in the Po Valley of northern Italy.

(c) If Genoa cyclogenesis is predicted, the following rules can be used to decide whether it will occur in the Gulf of Genoa or to the east in the Gulf of Venice:

1 If large amounts of cold air penetrate the Po Valley from the northeast, cyclogenesis can be expected in the Gulf of Genoa. This cyclone generally will move southeastward along the west coast of Italy.

2 If little cold air penetrates the Po Valley from the northeast while a strong push is observed in the Gulf of Lion, cyclogenesis will probable take place in the Gulf of Venice. This cyclone occasionally may move southeast through the Adriatic Sea.

(d) Genoa lows occur almost simultaneously with the onset of the Mistral in the Gulf of Lion, and invariably form when conditions are right for the Mistral to occur.

(e) Complex low pressure systems with multiple centers at the surface are a common event in the western Mediterranean Basin. One center usually can be found in the Gulf of Genoa, while another is found over North Africa; a weak pressure gradient exists between the two systems. Which of these lows will develop depends greatly on the movement of an upper-level (500 mb) short wave trough. If the trough moves to the North African coast, for example, the low center in that region will develop rapidly, increasing the pressure gradient and causing easterly gales over the southern Tyrrhenian Sea.

(2) Associated wind and weather

(a) Weak to moderate Genoa cyclogenesis causes important variations in the weather along the west coast of Italy. When analyzing these cases, the resolution of the 500 mg analysis should be fine enough to support tracing of the weak short wave troughs associated with increased shower activity.

(b) Convective activity associated with a genoa low has a periodicity of about 18 hr, starting with the initial cold frontal passage. The periodicity is most pronounced with a stationary low. The most intense convective activity occurs at 36 hr intervals.

(c) Strong northerly winds can be expected in the Gulf of Genoa within 6-8 hrs if (1) the 1034 mb isobar is present along the crest of the alps north of the Gulf of Genoa and (2) increasing northerly winds are observed at Milan.

(3) Miscellaneous

(a) A residual low pressure trough generally remains over the Gulf of Genoa even after the primary low has moved well out of the region. The trough can remain for several days.

(b) Centers of Genoa lows can be poorly organized: strong pressure gradients, associated with a lee trough south of the Alps, frequently are found far from the low's geographic center.

B. Strong Mistral outbreaks over the Gulf of Lion which, according to local authorities at Livorno, may spread eastward and cause strong southwesterly winds (Lebreccio) at Livorno. The following is an abbreviated listing of various guidelines which address the Mistral. For a more comprehensive listing, see the accompanying accompanying NEPRF Severe Weather Guide for Marseille or

Toulon, France.

(1). Frequency and rationale- According to Brody and Nestor (1980), strong westerly winds associated with Mistral conditions rarely reach the west coast of Italy. Local authorities at Livorno do not indicate frequency, but state that Lebeccio winds can blow as a result of a Mistral in the Gulf of Lion. The winds spread south of the Gulf and turn eastward. The induced low pressure in the Ligurian Sea assists the wind in turning until the direction becomes west-southwest in the Livorno area.

(2). Causes - According to Brody and Nestor (1980), the Mistral is the result of a combination of the following factors:

(a) A basic circulation that creates a pressure gradient from west to east along the coast of southern France. This pressure gradient is normally associated with Genoa cyclogenesis.

(b) A fall wind effect caused by cold air associated with the Mistral moving downslope as it approaches the southern coast of France and thus increasing the wind speed.

(c) A jet-effect wind increase caused by the orographic configuration of the coastline. This phenomenon is observed at the entrance to major mountain gaps such as the Carcassone Gap, Rhone Valley, and Durance Valley. It is also observed in the Strait of Bonifacio between Corsica and Sardinia.

(d) A wind increase over the open water resulting from the reduction in the braking effect of surface friction (as compared to the braking effect over land).

(3). Onset - A Mistral will start in the Gulf of Lion when one of three pressure differences is achieved: Perpignan - Marignane (Marseille), 3 mb;

Marignane - Nice, 3 mb; or Perpignan - Nice, 6 mb. A difference usually occurs from 0-24 hr after a closed Genoa low appears, but it occasionally occurs earlier.

(4). Intensity

(a) Strongest winds associated with a Mistral do not occur until after the passage of the upper level (500 mb) trough. This occurs well after the surface cold frontal passage.

(b) The table below may be used to estimate wind speed associated with a Mistral in the Gulf of Lion.

Pressure Difference (mb)	Perpignan* (station 07747) and Nice (station 07690)	Perpignan* and Marignane (station 07650	Marignane** and Nice
3		30-35 kt	30-35 kt
4		40	40
5		45-50	45-50
6	30-35 kt		
8	40		
10	45-50		

* Highest pressure at Perpignan
** Highest pressure at Marignane

(5). Extent - There is a rapid decrease in the frequency and average force of the Mistral east of Iles d'Hyeres. On many occasions, light easterlies are reported from Nice when strong northwesterlies are blowing at Marseille (Hydrographer of the Navy, 1965). Alongshore pressure gradient is important in predicting Mistral extent and intensity. When a 10 mb difference exists between Toulon and Nice, the Mistral will spread eastward. With only a 2 mb difference between Marseille and Toulon, the mistral will cease near Toulon. The eastern boundary of the Mistral usually extends downwind from the western edge of the Alps through San Remo, Italy (Brody and Nestor, 1980)

C. <u>Local indicators as related by local authorities.</u>

(1). <u>Onset</u>

(a) A common wind pattern at Livorno starts with light southeasterly winds (Scirocco), which veer to a southwesterly Lebeccio. The Lebeccio will usually take 4 to 6 hours to reach full force, thus providing a short advance warning before the strongest winds are experienced. The winds may last 2 to 3 days.

(b) Orographic clouds forming on the west side of Monte Nero, a 1,000 ft (305 m) peak east of Livorno, indicate the start of southwesterly winds.

(2). <u>Associated weather</u>

(a) If the winds veer to northerly after a Lebeccio event, the weather will improve, becoming cool and clear.

(b) If, following the Lebeccio, the winds become southeasterly, the weather will deteriorate and the Lebeccio will return later.

3.8.2 <u>General</u>

A. Past experience indicated that the reliability of hourly reporting stations along the Italian coast is questionable, especially during the night.

B. During periods of southerly surface flow in the central Mediterranean, convergence zones between southeasterly and southwesterly winds are frequently observed. These convergence zones result in heavier precipitation and lower visibilities. Fronts are not associated with this phenomenon initially, but may develop later.

C. During the winter half of the year along the west coast of Italy, maximum occurrence of convective activity is in the early morning (0300-0800L) and minimum occurrence is in the late afternoon and early evening. In the mountains to the east, however, this diurnal variation is reversed.

D. Dry, moderate-to-strong (15-25 kt), north-to east winds during the winter have produced steam fog along the Italian coast from Genoa to Pisa, (about 14 n mi north-northeast of Livorno) out to 35 n mi offshore. Visibilities in this fog are reduced to 1-2 n mi although the dewpoint-temperature spread measured at an aircraft carrier's flight deck level may exceed 4°F.

3.9 Summary of Problems, Actions, and Indicators

Table 3-2 is intended to provide easy to use seasonal references for meteorologists on ships using the Port of Livorno. Table 2-1 (Section 2) summarizes Table 3-2 and is intended primarily for use by ship captains.

Table 3-2. Potential problem situations at Port of Livorno, Italy - ALL SEASONS

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
1. Moored - inner harbor. Strongest in Winter Rare in Summer Occurs in Spring and Autumn	a. SW'ly winds/waves - Locally called Lebeccio, the winds are usually caused by low pressure systems in the Gulf of Genoa, but may result from Mistral winds which spread E from the Gulf of Lion. Winter velocities average force 6 to 7 (22-33 kt) but may reach force 8 to 9 (34-47 kt) for periods up to 12 hrs. Wind may persist for 2 to 3 days. Deep water waves of 10 to 13 ft (3 to 4 m) may be generated, with swell waves to 10 ft (3 m) lasting for 12-24 hrs after winds abate.	a. Moored vessels, especially those with large sail areas, may be forced on/off their berths by the wind. Line doubling may be required to prevent undue movement and shifting. The inner harbor is protected from hazardous wave action.	a. SW'ly Lebeccio winds are most often caused by Genoa lows, but may also be caused by an E'ly spreading of Mistral winds from the Gulf of Lion. The following is an abbreviated listing of various guidelines pertaining to Genoa lows and Mistral events. (1) Genoa lows. (a) Cyclogenesis 1. A lee trough often is present in the Gulf of Genoa when a cold or occluded front is moving into W France. The trough remains stationary until arrival of the front, at which time significant cyclogenesis occurs. 2. A good indication of rapid development of a Genoa low is the appearance of cold air from the NE in the Po Valley. 3. Genoa lows occur almost simultaneously with the onset of a Mistral in the Gulf of Lion, and invariably form when conditions are right for a Mistral to occur. (b) Associated weather: Convective activity associated with a Genoa low has a periodicity of about 18 hr, starting with the initial cold frontal passage, and is most pronounced with a stationary low. The most intense convective activity occurs at 36 hr intervals. (c) Miscellaneous 1. A residual low pressure trough generally remains over the Gulf of Genoa even after the primary low has moved well out of the region. The trough can remain several days. 2. Centers of Genoa lows can be poorly organized. Strong pressure gradients frequently are found far from the low's geographic center. (2) Mistral winds. Mistral winds only rarely reach the W coast of Italy. When occurring, they spread S of the Gulf of Lion and turn E. Induced low pressure over the Ligurian Sea aids the turning of the wind until the direction becomes WSW in the Livorno area. (a) Causes. The Mistral wind is the result of a combination of several factors, including: 1. A basic circulation that creates a W to E pressure gradient along the coast of S France. The pressure gradient is normally associated with Genoa cyclogenesis. 2. A fall wind effect caused by cold air moving downslope as it approaches the S coast of France. 3. A jet-effect wind increase caused by the orographic configuration of the coastline. 4. A wind increase over the open water resulting from the reduction in the braking effect of surface friction. (b) Onset. A Mistral will start in the Gulf of Lion when 1 of 3 pressure differences is achieved: Perpignan-Marignane (Marseille), 3 mb; Marignane-Nice, 3 mb; or Perpignan-Nice, 6 mb. A difference usually occurs from 0-24 hr after a closed Genoa low appears, but it occasionally occurs earlier. (c) Intensity. Strongest winds do not occur until after the passage of the upper-level (500 mb) trough. This occurs well after the surface cold frontal passage. (d) Extent. Alongshore pressure gradient is important in predicting Mistral extent. When a 10 mb pressure difference exists between Toulon and Nice, the Mistral will spread E. With only a 2 mb difference, the Mistral will cease near Toulon. The E boundary of the Mistral usually extends downwind from the W edge of the Alps through San Remo, Italy. (3) Local indicators. (a) Onset. 1. A common wind pattern at Livorno starts with light SE winds (Scirocco), which veer to SW (Lebeccio). The SW wind will usually take 4-6 hr to reach full force, so advance warning is built in. The winds may last 2 to 3 days. 2. Orographic clouds forming on the W side of Monte Nero, a 1,000 ft (305 m) peak E of Livorno, indicate the start of SW winds. (4) Associated weather. (a) If, following the Lebeccio, the winds become SE, the weather will deteriorate and the Lebeccio will return later. (b) If the winds veer to N after a Lebeccio event, the weather will improve, becoming cool and clear.

Table 3-2. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
2. <u>Anchored - outside breakwater</u>. Strongest in Winter Rare in Summer Occurs in Spring and Autumn	a. <u>SW'ly winds/waves</u> - Locally called Lebeccio, the winds are usually caused by low pressure systems in the Gulf of Genoa, but may result from Mistral winds which spread E from the Gulf of Lion. Winter velocities average force 6 to 7 (22-33 kt) but may reach force 8 to 9 (34-47 kt) for periods up to 12 hrs. Wind may persist for 2 to 3 days. Deep water waves of 10 to 13 ft (3 to 4 m) may be generated, with swell waves to 10 ft (3 m) lasting for 12-24 hrs after winds abate.	a. The Livorno anchorage is considered dangerous because high winds can produce hazardous sailing conditions which cause large vessels to drag anchors. Vessels in the roadstead are exposed to both winds and waves. Waves in the anchorage E of Secche della Meloria will likely be lower due to energy lost while crossing the relatively shallow bank. When winds are forecast to exceed 45 kt, the Port Captain will order vessels which are not berthed in the harbor to sortie and protect at sea. No viable alternate anchorages exist close to Livorno.	a. SW'ly Lebeccio winds are most often caused by Genoa lows, but may also be caused by an E'ly spreading of Mistral winds from the Gulf of Lion. The following is an abbreviated listing of various guidelines pertaining to Genoa lows and Mistral events. (1) <u>Genoa lows</u>. (a) <u>Cyclogenesis</u> <u>1</u>. A lee trough often is present in the Gulf of Genoa when a cold or occluded front is moving into W France. The trough remains stationary until arrival of the front, at which time significant cyclogenesis occurs. <u>2</u>. A good indication of rapid development of a Genoa low is the appearance of cold air from the NE in the Po Valley. <u>3</u>. Genoa lows occur almost simultaneously with the onset of a Mistral in the Gulf of Lion, and invariably form when conditions are right for a Mistral to occur. (b) <u>Associated weather</u>: Convective activity associated with a Genoa low has a periodicity of about 18 hr, starting with the initial cold frontal passage, and is most pronounced with a stationary low. The most intense convective activity occurs at 36 hr intervals. (c) <u>Miscellaneous</u> <u>1</u>. A residual low pressure trough generally remains over the Gulf of Genoa even after the primary low has moved well out of the region. The trough can remain several days. <u>2</u>. Centers of Genoa lows can be poorly organized. Strong pressure gradients frequently are found far from the low's geographic center. (2) <u>Mistral winds</u>. Mistral winds only rarely reach the W coast of Italy. When occurring, they spread S of the Gulf of Lion and turn E. Induced low pressure over the Ligurian Sea aids the turning of the wind until the direction becomes WSW in the Livorno area. (a) <u>Causes</u>. The Mistral wind is the result of a combination of several factors, including: <u>1</u>. A basic circulation that creates a W to E pressure gradient along the coast of S France. The pressure gradient is normally associated with Genoa cyclogenesis. <u>2</u>. A fall wind effect caused by cold air moving downslope as it approaches the S coast of France. <u>3</u>. A jet-effect wind increase caused by the orographic configuration of the coastline. <u>4</u>. A wind increase over the open water resulting from the reduction in the braking effect of surface friction. (b) <u>Onset</u>. A Mistral will start in the Gulf of Lion when 1 of 3 pressure differences is achieved: Perpignan-Marignane (Marseille), 3 mb; Marignane-Nice, 3 mb; or Perpignan-Nice, 6 mb. A difference usually occurs from 0-24 hr after a closed Genoa low appears, but it occasionally occurs earlier. (c) <u>Intensity</u>. Strongest winds do not occur until after the passage of the upper-level (500 mb) trough. This occurs well after the surface cold frontal passage. (d) <u>Extent</u>. Alongshore pressure gradient is important in predicting Mistral extent. When a 10 mb pressure difference exists between Toulon and Nice, the Mistral will spread E. With only a 2 mb difference, the Mistral will cease near Toulon. The E boundary of the Mistral usually extends downwind from the W edge of the Alps through San Remo, Italy. (3) <u>Local indicators</u>. (a) <u>Onset</u>. <u>1</u>. A common wind pattern at Livorno starts with light SE winds (Scirocco), which veer to SW (Lebeccio). The SW wind will usually take 4-6 hr to reach full force, so advance warning is built in. The winds may last 2 to 3 days. <u>2</u>. Orographic clouds forming on the W side of Monte Nero, a 1,000 ft (305 m) peak E of Livorno, indicate the start of SW winds. (4) <u>Associated weather</u>. (a) If, following the Lebeccio, the winds become SE, the weather will deteriorate and the Lebeccio will return later. (b) If the winds veer to N after a Lebeccio event, the weather will improve, becoming cool and clear.

Table 3-2. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
3. <u>Arriving/departing</u>. Strongest in Winter Rare in Summer Occurs in Spring and Autumn	a. <u>SW'ly winds/waves</u> - Locally called Lebeccio, the winds are usually caused by low pressure systems in the Gulf of Genoa, but may result from Mistral winds which spread E from the Gulf of Lion. Winter velocities average force 6 to 7 (22-33 kt) but may reach force 8 to 9 (34-47 kt) for periods up to 12 hrs. Wind may persist for 2 to 3 days. Deep water waves of 10 to 13 ft (3 to 4 m) may be generated, with swell waves to 10 ft (3 m) lasting for 12-24 hr after winds abate.	a. Vessels inbound to the inner harbor should consider the effects of strong winds on moorings and be prepared with additional mooring lines. Also, such vessels should be aware that strong SE'ly winds can create a SE'ly swell that is felt at Livorno, which at times makes it impossible for large vessels to enter the harbor. Vessels bound for the anchorage should know about the dangerous situation which exists during Lebeccio conditions, and be prepared to sortie if winds over 45 kt are forecast. No better anchorages exist close to Livorno. Vessels outbound from the inner harbor should prepare for waves to 13 ft (4 m). If winds are less than 45 kt and anchoring is desired, the area E of Secche della Meloria will likely afford lower wave heights. The N harbor entrance should be utilized for small boat runs to/from the anchorage and inner harbor.	a. SW'ly Lebeccio winds are most often caused by Genoa lows, but may also be caused by an E'ly spreading of Mistral winds from the Gulf of Lion. The following is an abbreviated listing of various guidelines pertaining to Genoa lows and Mistral events. (1) <u>Genoa lows</u>. (a) <u>Cyclogenesis</u> <u>1</u>. A lee trough often is present in the Gulf of Genoa when a cold or occluded front is moving into W France. The trough remains stationary until arrival of the front, at which time significant cyclogenesis occurs. <u>2</u>. A good indication of rapid development of a Genoa low is the appearance of cold air from the NE in the Po Valley. <u>3</u>. Genoa lows occur almost simultaneously with the onset of a Mistral in the Gulf of Lion, and invariably form when conditions are right for a Mistral to occur. (b) <u>Associated weather</u>: Convective activity associated with a Genoa low has a periodicity of about 18 hr, starting with the initial cold frontal passage, and is most pronounced with a stationary low. The most intense convective activity occurs at 36 hr intervals. (c) <u>Miscellaneous</u> <u>1</u>. A residual low pressure trough generally remains over the Gulf of Genoa even after the primary low has moved well out of the region. The trough can remain several days. <u>2</u>. Centers of Genoa lows can be poorly organized. Strong pressure gradients frequently are found far from the low's geographic center. (2) <u>Mistral winds</u>. Mistral winds only rarely reach the W coast of Italy. When occurring, they spread S of the Gulf of Lion and turn E. Induced low pressure over the Ligurian Sea aids the turning of the wind until the direction becomes WSW in the Livorno area. (a) <u>Causes</u>. The Mistral wind is the result of a combination of several factors, including: <u>1</u>. A basic circulation that creates a W to E pressure gradient along the coast of S France. The pressure gradient is normally associated with Genoa cyclogenesis. <u>2</u>. A fall wind effect caused by cold air moving downslope as it approaches the S coast of France. <u>3</u>. A jet-effect wind increase caused by the orographic configuration of the coastline. <u>4</u>. A wind increase over the open water resulting from the reduction in the braking effect of surface friction. (b) <u>Onset</u>. A Mistral will start in the Gulf of Lion when 1 of 3 pressure differences is achieved: Perpignan-Marignane (Marseille), 3 mb; Marignane-Nice, 3 mb; or Perpignan-Nice, 6 mb. A difference usually occurs from 0-24 hr after a closed Genoa low appears, but it occasionally occurs earlier. (c) <u>Intensity</u>. Strongest winds do not occur until after the passage of the upper-level (500 mb) trough. This occurs well after the surface cold frontal passage. (d) <u>Extent</u>. Alongshore pressure gradient is important in predicting Mistral extent. When a 10 mb pressure difference exists between Toulon and Nice, the Mistral will spread E. With only a 2 mb difference, the Mistral will cease near Toulon. The E boundary of the Mistral usually extends downwind from the W edge of the Alps through San Remo, Italy. (3) <u>Local indicators</u>. (a) <u>Onset</u>. <u>1</u>. A common wind pattern at Livorno starts with light SE winds (Scirocco), which veer to SW (Lebeccio). The SW wind will usually take 4-6 hr to reach full force, so advance warning is built in. The winds may last 2 to 3 days. <u>2</u>. Orographic clouds forming on the W side of Monte Nero, a 1,000 ft (305 m) peak E of Livorno, indicate the start of SW winds. (4) <u>Associated weather</u>. (a) If, following the Lebeccio, the winds become SE, the weather will deteriorate and the Lebeccio will return later. (b) If the winds veer to N after a Lebeccio event, the weather will improve, becoming cool and clear.

Table 3-2. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
4. Small boats. Strongest in Winter Rare in Summer Occurs in Spring and Autumn	a. SW'ly winds/waves - Locally called Lebeccio, the winds are usually caused by low pressure systems in the Gulf of Genoa, but may result from Mistral winds which spread E from the Gulf of Lion. Winter velocities average force 6 to 7 (22-33 kt) but may reach force 8 to 9 (34-47 kt) for periods up to 12 hr. Wind may persist for 2 to 3 days. Deep water waves of 10 to 13 ft (3 to 4 m) may be generated, with swell waves to 10 ft (3 m) lasting for 12-24 hr after winds abate.	a. Small boats will normally continue operations until winds exceed force 4 (11-16 kt). Because of the protective effects of shallow water over Secche della Meloria, boats making runs to/from the harbor and the anchorages may find it less hazardous to use the N harbor entrance.	a. SW'ly Lebeccio winds are most often caused by Genoa lows, but may also be caused by an E'ly spreading of Mistral winds from the Gulf of Lion. The following is an abbreviated listing of various guidelines pertaining to Genoa lows and Mistral events. (1) Genoa lows. (a) Cyclogenesis 1. A lee trough often is present in the Gulf of Genoa when a cold or occluded front is moving into W France. The trough remains stationary until arrival of the front, at which time significant cyclogenesis occurs. 2. A good indication of rapid development of a Genoa low is the appearance of cold air from the NE in the Po Valley. 3. Genoa lows occur almost simultaneously with the onset of a Mistral in the Gulf of Lion, and invariably form when conditions are right for a Mistral to occur. (b) Associated weather: Convective activity associated with a Genoa low has a periodicity of about 18 hr, starting with the initial cold frontal passage, and is most pronounced with a stationary low. The most intense convective activity occurs at 36 hr intervals. (c) Miscellaneous 1. A residual low pressure trough generally remains over the Gulf of Genoa even after the primary low has moved well out of the region. The trough can remain several days. 2. Centers of Genoa lows can be poorly organized. Strong pressure gradients frequently are found far from the low's geographic center. (2) Mistral winds. Mistral winds only rarely reach the W coast of Italy. When occurring, they spread S of the Gulf of Lion and turn E. Induced low pressure over the Ligurian Sea aids the turning of the wind until the direction becomes WNW in the Livorno area. (a) Causes. The Mistral wind is the result of a combination of several factors, including: 1. A basic circulation that creates a W to E pressure gradient along the coast of S France. The pressure gradient is normally associated with Genoa cyclogenesis. 2. A fall wind effect caused by cold air moving downslope as it approaches the S coast of France. 3. A jet-effect wind increase caused by the orographic configuration of the coastline. 4. A wind increase over the open water resulting from the reduction in the braking effect of surface friction. (b) Onset. A Mistral will start in the Gulf of Lion when 1 of 3 pressure differences is achieved: Perpignan-Marignane (Marseille), 3 mb; Marignane-Nice, 3 mb; or Perpignan-Nice, 6 mb. A difference usually occurs from 0-24 hr after a closed Genoa low appears, but it occasionally occurs earlier. (c) Intensity. Strongest winds do not occur until after the passage of the upper-level (500 mb) trough. This occurs well after the surface cold frontal passage. (d) Extent. Alongshore pressure gradient is important in predicting Mistral extent. When a 10 mb pressure difference exists between Toulon and Nice, the Mistral will spread E. With only a 2 mb difference, the Mistral will cease near Toulon. The E boundary of the Mistral usually extends downwind from the W edge of the Alps through San Remo, Italy. (3) Local indicators. (a) Onset. 1. A common wind pattern at Livorno starts with light SE winds (Scirocco), which veer to SW (Lebeccio). The SW wind will usually take 4-6 hr to reach full force, so advance warning is built in. The winds may last 2 to 3 days. 2. Orographic clouds forming on the W side of Monte Nero, a 1,000 ft (305 m) peak E of Livorno, indicate the start of SW winds. (4) Associated weather. (a) If, following the Lebeccio, the winds become SE, the weather will deteriorate and the Lebeccio will return later. (b) If the winds veer to N after a Lebeccio event, the weather will improve, becoming cool and clear.

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Port Visit Information

August 1987: NEPRF Meteorologist R. Fett and D. Perryman met with acting Port Captain CDR Scarascia and Chief Pilot Picchi to obtain much of the information included in this port evaluation.

APPENDIX A

General Purpose Oceanographic Information

This section provides general information on wave forecasting and wave climatology as used in this study. The forecasting material is not harbor specific. The material in paragraphs A.1 and A.2 was extracted from H.O. Pub. No. 603, Practical Methods for Observing and Forecasting Ocean Waves (Pierson, Neumann, and James, 1955). The information on fully arisen wave conditions (A.3) and wave conditions within the fetch region (A.4) is based on the JONSWAP model. This model was developed from measurements of wind wave growth over the North Sea in 1973. The JONSWAP model is considered more appropriate for an enclosed sea where residual wave activity is minimal and the onset and end of locally forced wind events occur rapidly (Thornton, 1986), and where waves are fetch limited and growing (Hasselmann, et al., 1976). Enclosed sea, rapid onset/subsiding local winds, and fetch limited waves are more representative of the Mediterranean waves and winds than the conditions of the North Atlantic from which data was used for the Pierson and Moskowitz (P-M) Spectra (Neumann and Pierson 1966). The P-M model refined the original spectra of H.O. 603, which over developed wave heights.

The primary difference in the results of the JONSWAP and P-M models is that it takes the JONSWAP model longer to reach a given height or fully developed seas. In part this reflects the different starting wave conditions. Because the propagation of waves from surrounding areas into semi-enclosed seas, bays, harbors, etc. is limited, there is little residual wave action following periods of locally light/calm winds and the sea surface is nearly flat. A local wind developed wave growth is therefore slower than wave growth in the open ocean where some residual wave action is generally always present. This slower wave development is a built in bias in the formulation of the JONSWAP model which is based on data collected in an enclosed sea.

A.1 Definitions

Waves that are being generated by local winds are called "SEA". Waves that have traveled out of the generating area are known as "SWELL". Seas are chaotic in period, height and direction while swell approaches a simple sine wave pattern as its distance from the generating area increases. An in-between state exists for a few hundred miles outside the generating area and is a condition that reflects parts of both of the above definitions. In the Mediterranean area, because its fetches and open sea expanses are limited, SEA or IN- BETWEEN conditions will prevail. The "SIGNIFICANT WAVE HEIGHT" is defined as the average value of the heights of the one-third highest waves. PERIOD and WAVE LENGTH refer to the time between passage of, and distances between, two successive crests on the sea surface. The FREQUENCY is the reciprocal of the period ($f = 1/T$) therefore as the period increases the frequency decreases. Waves result from the transfer of energy from the wind to the sea surface. The area over which the wind blows is known as the FETCH, and the length of time that the wind has blown is the DURATION. The characteristics of waves (height, length, and period) depend on the duration, fetch, and velocity of the wind. There is a continuous generation of small short waves from the time the wind starts until it stops. With continual transfer of energy from the wind to the sea surface the waves grow with the older waves leading the growth and spreading the energy over a greater range of frequencies. Throughout the growth cycle a SPECTRUM of ocean waves is being developed.

A.2 Wave Spectrum

Wave characteristics are best described by means of their range of frequencies and directions or their spectrum and the shape of the spectrum. If the spectrum of the waves covers a wide range of frequencies and directions (known as short-crested conditions), SEA conditions prevail. If the spectrum covers a narrow range of frequencies and directions (long crested conditions), SWELL conditions prevail. The wave spectrum depends on the duration of the wind, length of the fetch, and on the wind velocity. At a given wind speed and a given state of wave development, each spectrum has a band of frequencies where most of the total energy is concentrated. As the wind speed increases the range of significant frequencies extends more and more toward lower frequencies (longer periods). The frequency of maximum energy is given in equation 1.1 where v is the wind speed in knots.

$$f_{max} = \frac{2.476}{v} \qquad (1.1)$$

The wave energy, being a function of height squared, increases rapidly as the wind speed increases and the maximum energy band shifts to lower frequencies. This results in the new developing smaller waves (higher frequencies) becoming less significant in the energy spectrum as well as to the observer. As larger waves develop an observer will pay less and less attention to the small waves. At the low frequency (high period) end the energy drops off rapidly, the longest waves are relatively low and extremely flat, and therefore also masked by the high energy frequencies. The result is that 5% of the upper frequencies and 3% of the lower frequencies can be cut-off and only the remaining frequencies are considered as the "significant part of the wave spectrum". The resulting range of significant frequencies or periods are used in defining a fully arisen sea. For a fully arisen sea the approximate average period for a given wind speed can be determined from equation (1.2).

$$\bar{T} = 0.285v \qquad (1.2)$$

Where v is wind speed in knots and T is period in seconds. The approximate average wave length in a fully arisen sea is given by equation (1.3).

$$\bar{L} = 3.41\ \bar{T}^2 \qquad (1.3)$$

Where $\bar{L}$ is average wave length in feet and $\bar{T}$ is average period in seconds.

The approximate average wave length of a fully arisen sea can also be expressed as:

$$\bar{L} = .67\text{"L"} \qquad (1.4)$$

where "L" = $5.12T^2$, the wave length for the classic sine wave.

A.3 Fully Arisen Sea Conditions

For each wind speed there are minimum fetch (n mi) and duration (hr) values required for a fully arisen sea to exist. Table A-1 lists minimum fetch and duration values for selected wind speeds, values of significant wave (average of the highest 1/3 waves) period and height, and wave length of the average wave during developing and fully arisen seas. The minimum duration time assumes a start from a flat sea. When pre-existing lower waves exist the time to fetch limited height will be shorter. Therefore the table duration time represents the maximum duration required.

Table A-1. Fully Arisen Deep Water Sea Conditions Based on the JONSWAP Model.

Wind Speed (kt)	Minimum Fetch/Duration (n mi) / (hrs)	Sig Wave (H1/3) Period/Height (sec) / (ft)	Wave Length (ft)[1,2] Developing/Fully /Arisen L X (.5) /L X (.67)
10	28 / 4	4 / 2	41 / 55
15	55 / 6	6 / 4	92 / 123
20	110 / 8	8 / 8	164 / 220
25	160 / 11	9 / 12	208 / 278
30	210 / 13	11 / 16	310 / 415
35	310 / 15	13 / 22	433 / 580
40	410 / 17	15 / 30	576 / 772

NOTES:

[1] Depths throughout fetch and travel zone must be greater than 1/2 the wave length, otherwise shoaling and refraction take place and the deep water characteristics of waves are modified.

[2] For the classic sine wave the wave length (L) equals 5.12 times the period (T) squared ($L = 5.12T^2$). As waves develop and mature to fully developed waves and then propagate out of the fetch area as swell their wave lengths approach the classic sine wave length. Therefore the wave lengths of developing waves are less than those of fully developed waves which in turn are less than the length of the resulting swell. The factor of .5 (developing) and .67 (fully developed) reflect this relationship.

A.4 Wave Conditions Within The Fetch Region

Waves produced by local winds are referred to as SEA. In harbors the local sea or wind waves may create hazardous conditions for certain operations. Generally within harbors the fetch lengths will be short and therefore the growth of local wind waves will be fetch limited. This implies that there are locally determined upper limits of wave height and period for each wind velocity. Significant changes in speed or direction will result in generation of a new wave group with a new set of height and period limits. Once a fetch limited sea reaches its upper limits no further growth will occur unless the wind speed increases.

Table A-2 provides upper limits of period and height for given wind speeds over some selected fetch lengths. The duration in hours required to reach these upper limits (assuming a start from calm and flat sea conditions) is also provided for each combination of fetch length and wind speed. Some possible uses of Table A-2 information are:

1) If the only waves in the area are locally generated wind waves, the Table can be used to forecast the upper limit of sea conditions for combinations of given wind speeds and fetch length.

2) If deep water swell is influencing the local area in addition to locally generated wind waves, then the Table can be used to determine the wind waves that will combine with the swell. Shallow water swell conditions are influenced by local bathymetry (refraction and shoaling) and will be addressed in each specific harbor study.

3) Given a wind speed over a known fetch length the maximum significant wave conditions and time needed to reach this condition can be determined.

Table A-2. Fetch Limited Wind Wave Conditions and Time Required to Reach These Limits (Based on JONSWAP Model). Enter the table with wind speed and fetch length to determine the significant wave height and period, and time duration needed for wind waves to reach these limiting factors. All of the fetch/speed combinations are fetch limited except the 100 n mi fetch and 18 kt speed.

<u>Format:</u> height (feet)/period (seconds)
duration required (hours)

Fetch Length (n mi) \ Wind Speed (kt)	18	24	30	36	42
10	2/3-4 1-2	3/3-4 2	3-4/4 2	4/4-5 1-2	5/5 1-2
20	3/4-5 2-3	4/4-5 3	5/5 3	6/5-6 3-4	7/5-6 3
30	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3
40	4-5/5-6 4-5	5/6 4	6-7/6-7 4	8/7 4	9-10/7-8 3-4
100	5/6-7[1] 5-6	9/8 8	11/9 7	13/9 7	15-16/9-10 7

[1] 18 kt winds are not fetch limited over a 100 n mi fetch.

An example of expected wave conditions based on Table A-2 follows:

<u>WIND FORECAST OR CONDITION</u>

An offshore wind of about 24 kt with a fetch limit of 20 n mi (ship is 20 n mi from the coast) is forecast or has been occurring.

<u>SEA FORECAST OR CONDITION</u>

From Table A-2: If the wind condition is forecast to last, or has been occurring, for at least 3 hours:

Expect sea conditions of 4 feet at 4-5 second period to develop or exist. If the condition lasts less than 3 hours the seas will be lower. If the condition lasts beyond 3 hours the sea will not grow beyond that developed at the end of about 3 hours unless there is an increase in wind speed or a change in the direction that results in a longer fetch.

A.5 Wave Climatology

The wave climatology used in these harbor studies is based on 11 years of Mediterranean SOWM output. The MED-SOWM is discussed in Volume II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual (1986). A deep water MED-SOWM grid point was selected as representative of the deep water wave conditions outside each harbor. The deep water waves were then propagated into the shallow water areas. Using linear wave theory and wave refraction computations the shallow water climatology was derived from the modified deep water wave conditions. This climatology does not include the local wind generated seas. This omission, by design, is accounted for by removing all wave data for periods less than 6 seconds in the climatology. These shorter period waves are typically dominated by locally generated wind waves.

A.6 Propagation of Deep Water Swell Into Shallow Water Areas

When deep water swell moves into shallow water the wave patterns are modified, i.e., the wave heights and directions typically change, but the wave period remains constant. Several changes may take place including shoaling as the wave feels the ocean bottom, refraction as the wave crest adjusts to the bathymetry pattern, changing so that the crest becomes more parallel to the bathymetry contours, friction with the bottom sediments, interaction with currents, and adjustments caused by water temperature gradients. In this work, only shoaling and refraction effects are considered. Consideration of the other factors are beyond the resources available for this study and, furthermore, they are considered less significant in the harbors of this study than the refraction and shoaling factors.

To determine the conditions of the deep water waves in the shallow water areas the deep water conditions were first obtained from the Navy's operational MED-SOWM wave model. The bathymetry for the harbor/area of interest was extracted from available charts and digitized for computer use. Figure A-1 is a sample plot of bathymetry as used in this project. A ray path refraction/shoaling program was run for selected combinations of deep water wave direction and period. The selection was based on the near deep water wave climatology and harbor exposure. Each study area requires a number of ray path computations. Typically there are 3 or 4 directions (at 30° increments) and 5 or 6 periods (at 2 second intervals) of concern for each area of study. This results in 15 to 24 plots per area/harbor. To reduce this to a manageable format for quick reference, specific locations within each study area were selected and the information was summarized and is presented in the specific harbor studies in tabular form.

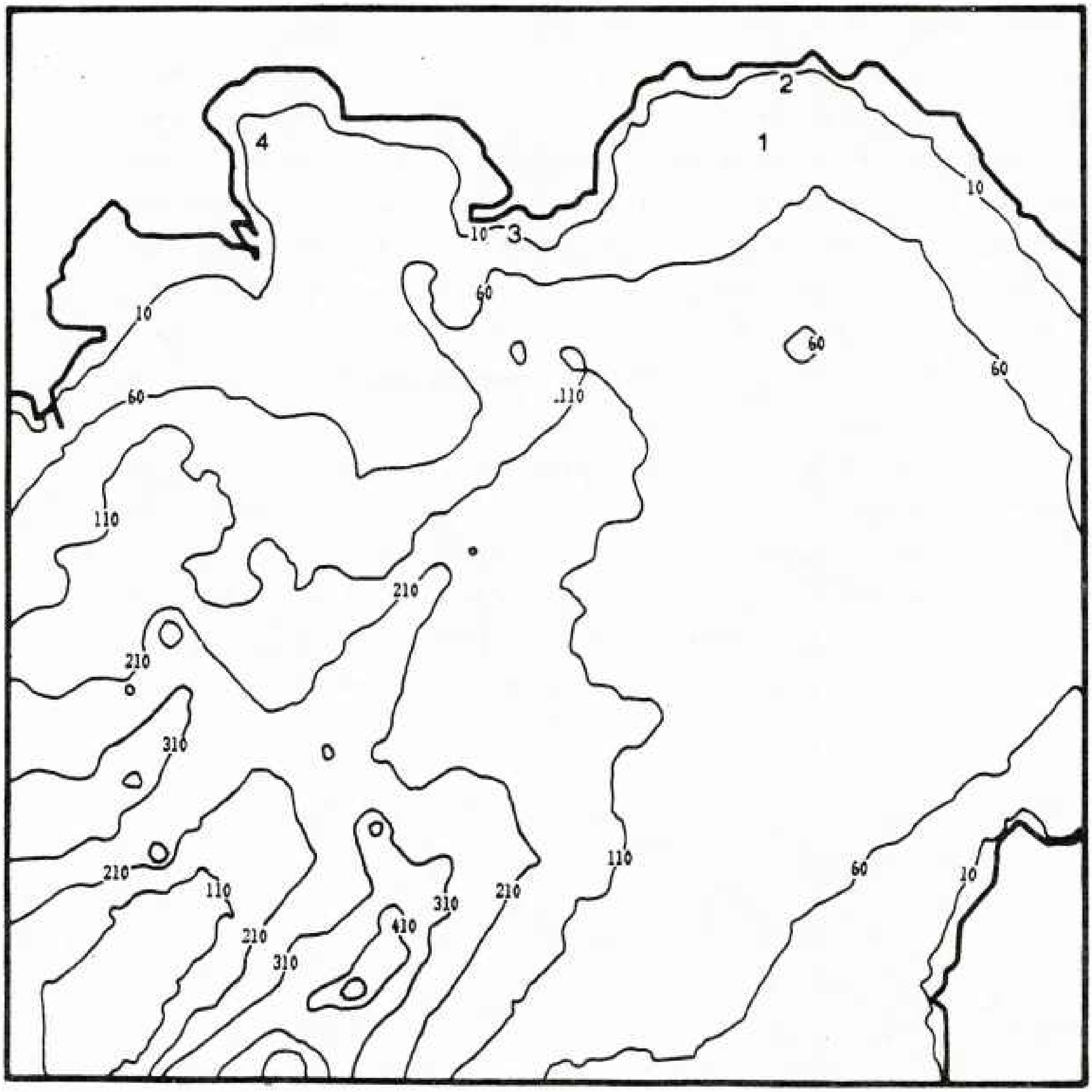

Figure A-1. Example plot of bathymetry (Naples harbor) as used in this project. For plotting purposes only, contours are at 50 fathom intervals from an initial 10 fathoms to 110 fathoms, and at 100 fathom intervals thereafter. The larger size numbers identify specific anchorage areas addressed in the harbor study.

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